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THE POPULATION DYNAMICS OF THE SPOTTED TURTLE, *CLEMMYS GUTATTA*, ON CARROLL ISLAND

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June 1983

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The population dynamics and structure of the spotted turtle, *Clemmys guttata* were studies from 1970 until 1982. Carroll Island was the site of chemical testing from post WW II until 1971. Special consideration was given to the impact upon the populations of turtles by the chemicals released on Carroll Island.

Several findings are noteworthy. The number of juveniles on the island has steadily declined over the 12 years of sampling. The current (1982)

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population is half of that estimated for 1972-73. The proportion of females dropped as low as 0.25 of the population. Four possible hypotheses are delivered to explain the observations. The most likely explanations are that a temperature anomaly or natural catastrophe dramatically reduced the proportion of females present. At the same time the population of turtles overshot the carrying capacity of the environment after cessation of an artificial or natural constraint.

PREFACE

This report is an attempt to follow a natural population of the spotted turtle, *Clemmys guttata*, over a 12-year period. Such a program or opportunity is rare in herpetological studies. As such, the program has provided interesting and exciting insights into the fluid dynamics of a long-lived, climax species.

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THE POPULATION DYNAMICS OF THE SPOTTED TURTLE, *Clemmys guttata*, ON CARROLL ISLAND

1 INTRODUCTION

Since 1970 the populations of the spotted turtle, *Clemmys guttata*, have been studied on Carroll Island, Aberdeen Proving Ground, Maryland. Carroll Island was the site of chemical pollution from just after World War II until 1971. The types, quantities, and distribution of the chemical material used on the test site have been described in detail by Ward.[1] From July 1964 until December 1971, 12,631.8 lb (5729.8 kg) of materials were deposited on the experimental (HOT) area of Carroll Island.

The aim of the study reported here was an analysis of the population dynamics of the populations of *C. guttata* over a 12-year period, from 1970 until 1982. Special consideration was given to the impact upon the populations of the chemicals released on Carroll Island.

2 METHODS AND MATERIALS

Carroll Island is a peninsula of the Chesapeake Bay located in Baltimore County, Maryland. It is currently part of the Aberdeen Proving Grounds. The island is separated into control (COLD) and experimental (HOT) areas that are divided by a fence (figure 1). The surface cover is composed of woodlot, tidal marsh, and mowed fields. Several large ponds exist on the island, especially on the COLD segment. The habitats of the sampling areas were compared to maps produced by Ward[1] in 1970-71. Alterations in habitat were recorded.

Estimation of population size of spotted turtles using mark-recapture data was done previously using the Jolly-Seber program. The assumptions included: equal catchability of the turtles, equal effort expended by the collectors, availability of the previous year's data, and sufficient sample size. The advantage of this technique is the calculation of confidence intervals.

The study described here used a more basic mark-recapture technique in order to approximate the number of turtles inhabiting the sampling areas on Carroll Island. Each year's data were treated as an independent sample. Since the turtles were sampled with replacement, the total number of captures exceeded the actual number of individual turtles collected.

The calculations of population size were based on the following: Let N = population size, M = number of individual turtles marked, C = total number of captures, r = total number of recaptures. The assumption was that:

$$\frac{N}{M} = \frac{C}{r} \qquad (1)$$

and rearranging

$$N = M\frac{C}{r} \quad . \qquad (2)$$

Confidence intervals were estimated by taking advantage of the negative binomial recapture distribution. Since the negative binomial approaches the

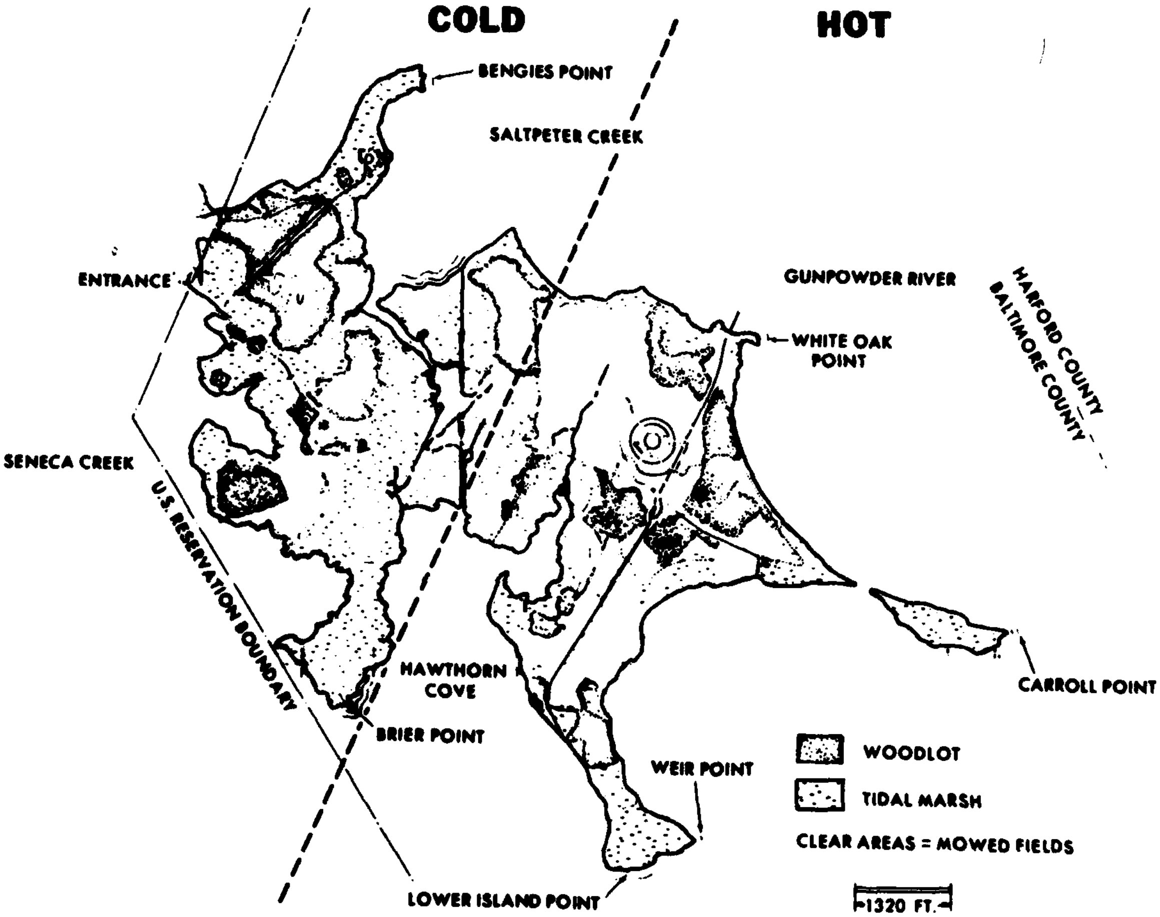

Figure 1. Carroll Island Separated into COLD and HOT Areas

Poisson distribution at large sample sizes, the confidence interval was estimated using the Poisson. The confidence interval calculated in this manner is likely to be an underestimate, but experience[2] has shown the confidence intervals calculated from a negative binomial to be unrealisticly high in many cases. Additionally, the sample variance of the mark-recapture data always proved to be much less than twice the value of the mean (see table 1). In a Poisson distribution the mean and variance are equal.

3 RESULTS

Histograms of 5mm-size intervals were constructed to examine the size distribution of the captured turtles. Adult size exhibited a mode of the 96mm- to 100mm-interval during the 12-year period of this study. In fact, the size distribution around the mode was suprisingly symmetrical, resembling a multivariate distribution (figure 2). The resemblance to a multivariate distribution was expected since size is a trait determined by numerous genes. Assuming a multivariate type distribution, examination of the histogram provided a range of adult size from the 91mm- to 95mm-interval to the 111mm- to 115mm-interval. This estimate corresponded well to previous estimates of minimum adult size in *C. guttata* of 92mm.[3,4,5]

The spatial distribution of the turtles was contagious (clumped). Ward[1] demonstrated this fact by mapping the capture sites of the turtles. The fit of the capture distribution of the spotted turtles to a negative binomial (table 1) statistically confirms the observation.[6]

Three interrelated factors, population size, proportion of juveniles, and sex ratio, changed greatly during the 12-year period of this study. The estimate of population size ranged from a peak of 2324 turtles in 1974 to a current low of 852 in 1982 (figure 3). The proportion of juveniles on the island also declined (figure 4). In 1971 the proportion of juveniles (size less than 90mm) on Carroll Island was 33.4 percent, by 1982 it dropped to 12.1 percent of the captured population. In each year the proportion of juveniles was higher in the HOT area (figure 5). The sex ratios of the adult populations ranged from 50 percent female in 1970 to 25.1 percent female in 1972, followed by a gradual rise to 49.2 percent female in 1981 (figure 6).

Turtles, in general, are long-lived species that are virtually invulnerable to predation upon reaching adult size. Serveral *C. guttata* captured during 1970-71 as adults (size greater than 91mm) were recaptured during 1982. Assuming it takes spotted turtles 9 years to reach maturity, these animals were at least 20-21 years of age.

4 DISCUSSION

Several hypotheses can be offered to explain the population dynamics of the population of turtles on Carroll Island. All hypotheses assume that the apparent rise in the population observed in 71-74 was real. In support of the assumption is the large proportion of juveniles in the population. The increase could be due to the end of the testing of chemical materials on the island or the relaxation of a natural constraint. Alternatively, the increase may have been a normal cycle in population size as is known in small mammals. However, vetebrates that exhibit long lifetimes, low reproductive potential, general invulnerability

Table 1. Analysis of Capture Distribution of *C. guttata* for 1975

						Total
Number of time recaptured	x	0	1	2	3	n
Number of turtles	f	207	26	10	1	244

Sample mean $\bar{X}_{75} = \frac{fx}{n} = 0.201$

Sample variance $S^2_{75} = \frac{fx^2 - \bar{x} \quad fx}{n - 1} = 0.264$

Predicted distribution calculated from a negative binomial

x	0	1	2	3
f	204.8	31.4	6.2	1.3

Chi-square (X^2) goodness of fit test performed to compare observed versus predicted distributions. Chi-square value = $2.680 < 7.815 = X^2_{.95}$, with three degrees of freedom. Therefore, the capture distribution is not significantly different from a negative binomial distribution.

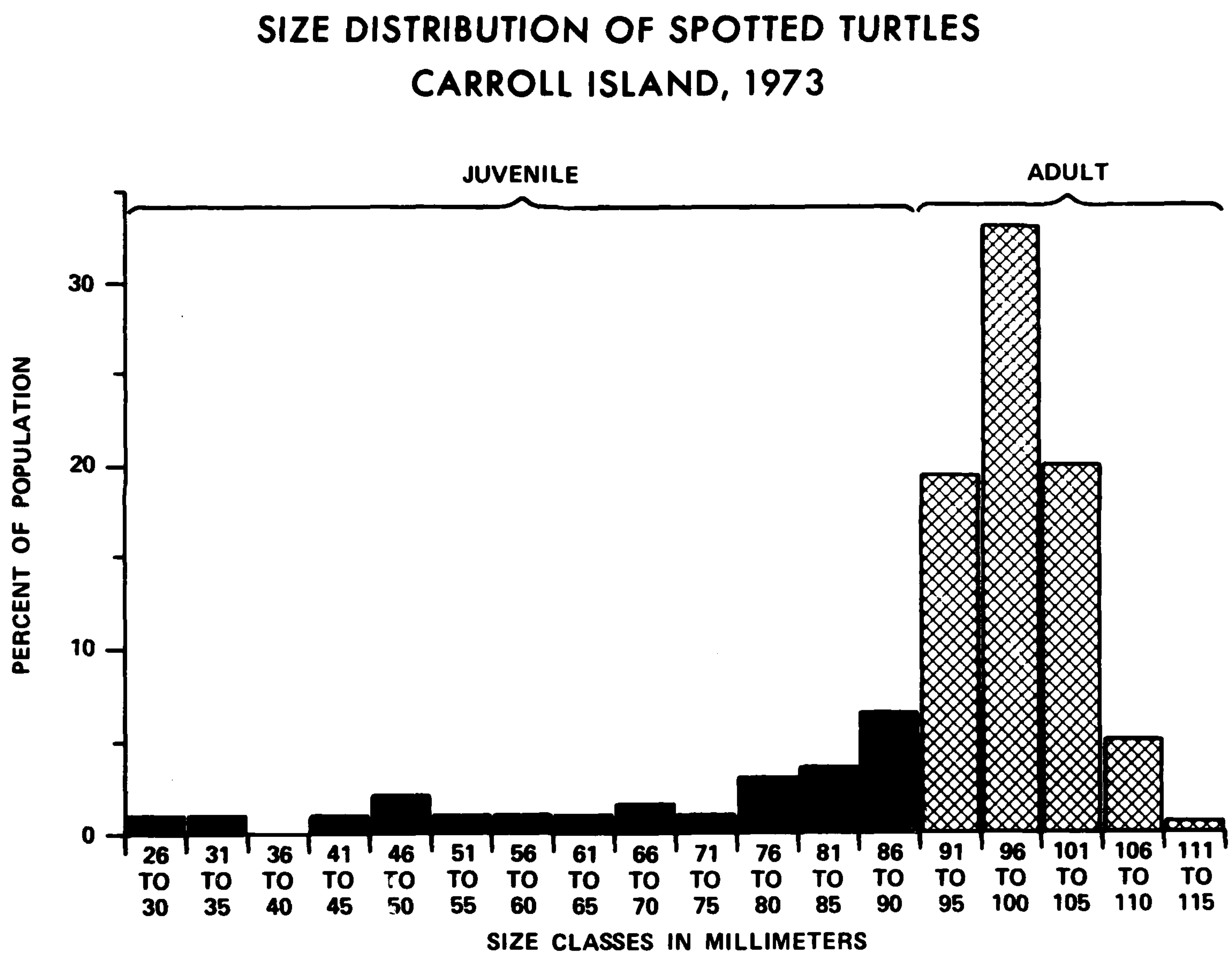

Figure 2. Size Distribution of Spotted Turtles

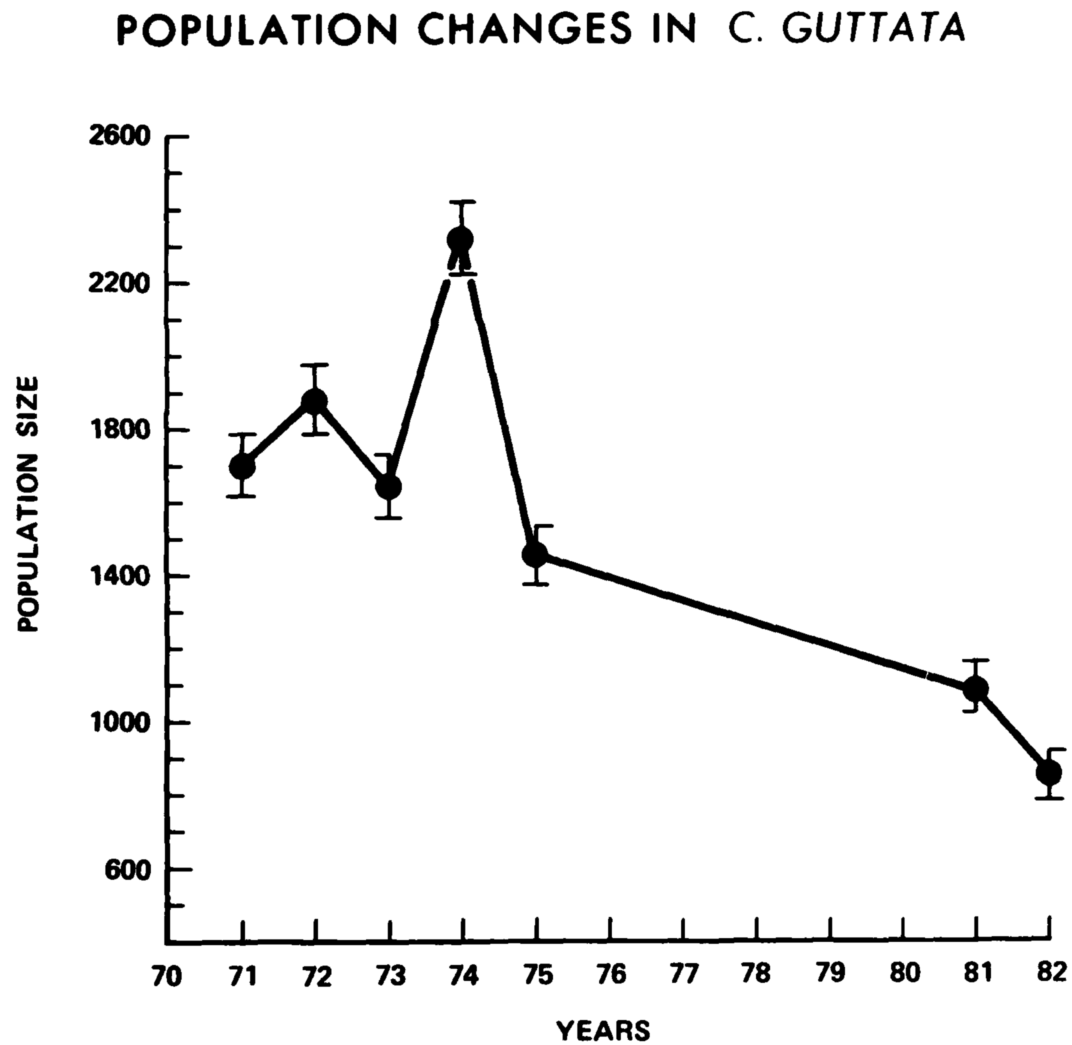

Figure 3. Population Changes in *C. guttata*

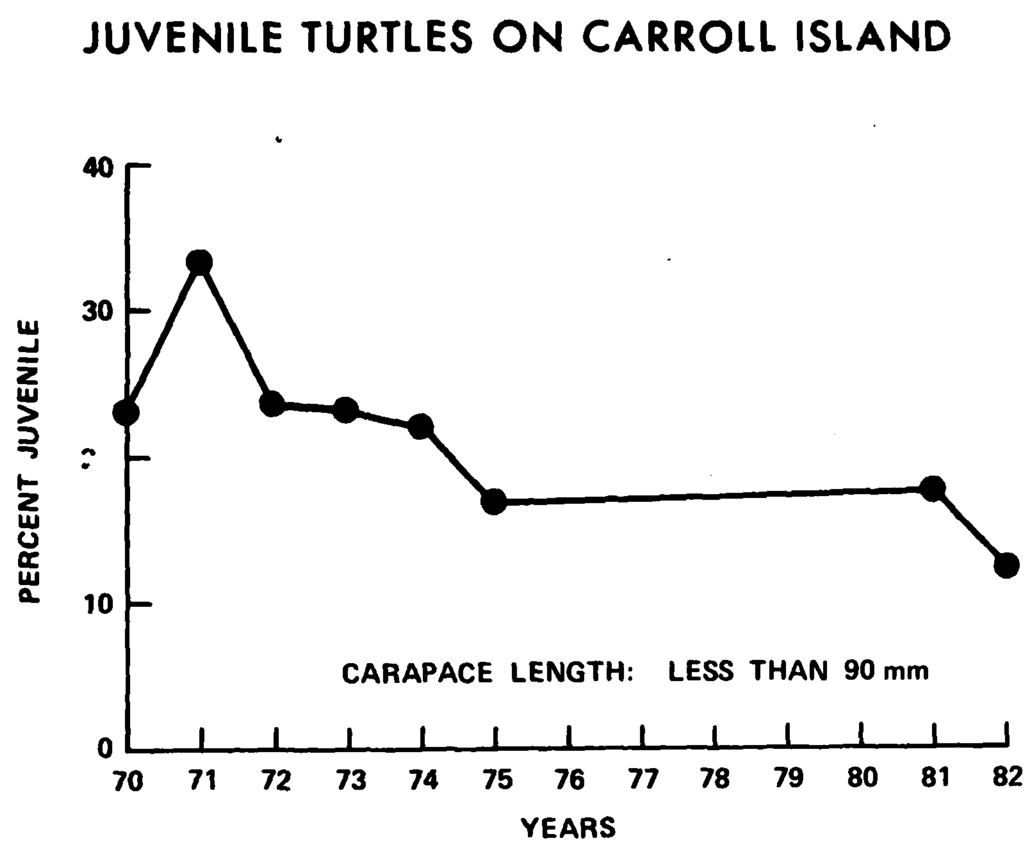

Figure 4. Juvenile Turtles on Carroll Island

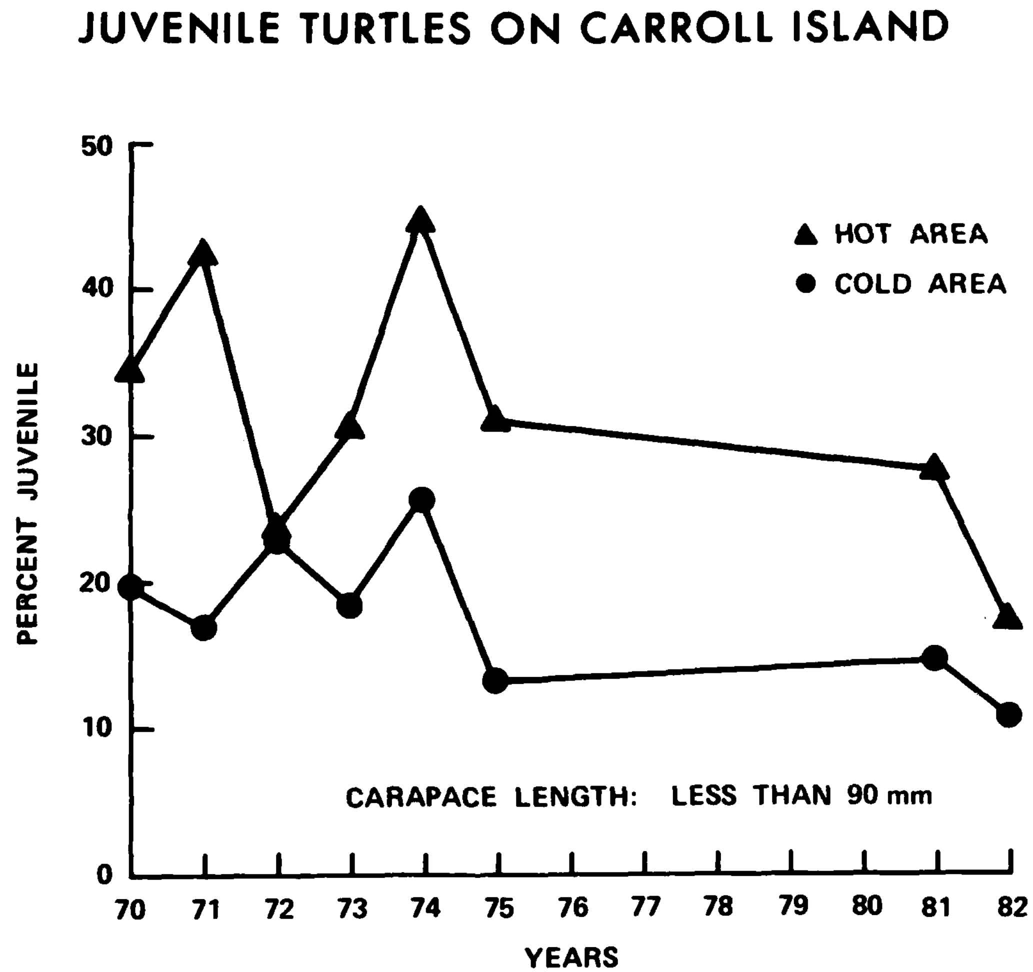

Figure 5. Juvenile Turtles on Carroll Island (HOT Area Versus COLD Area)

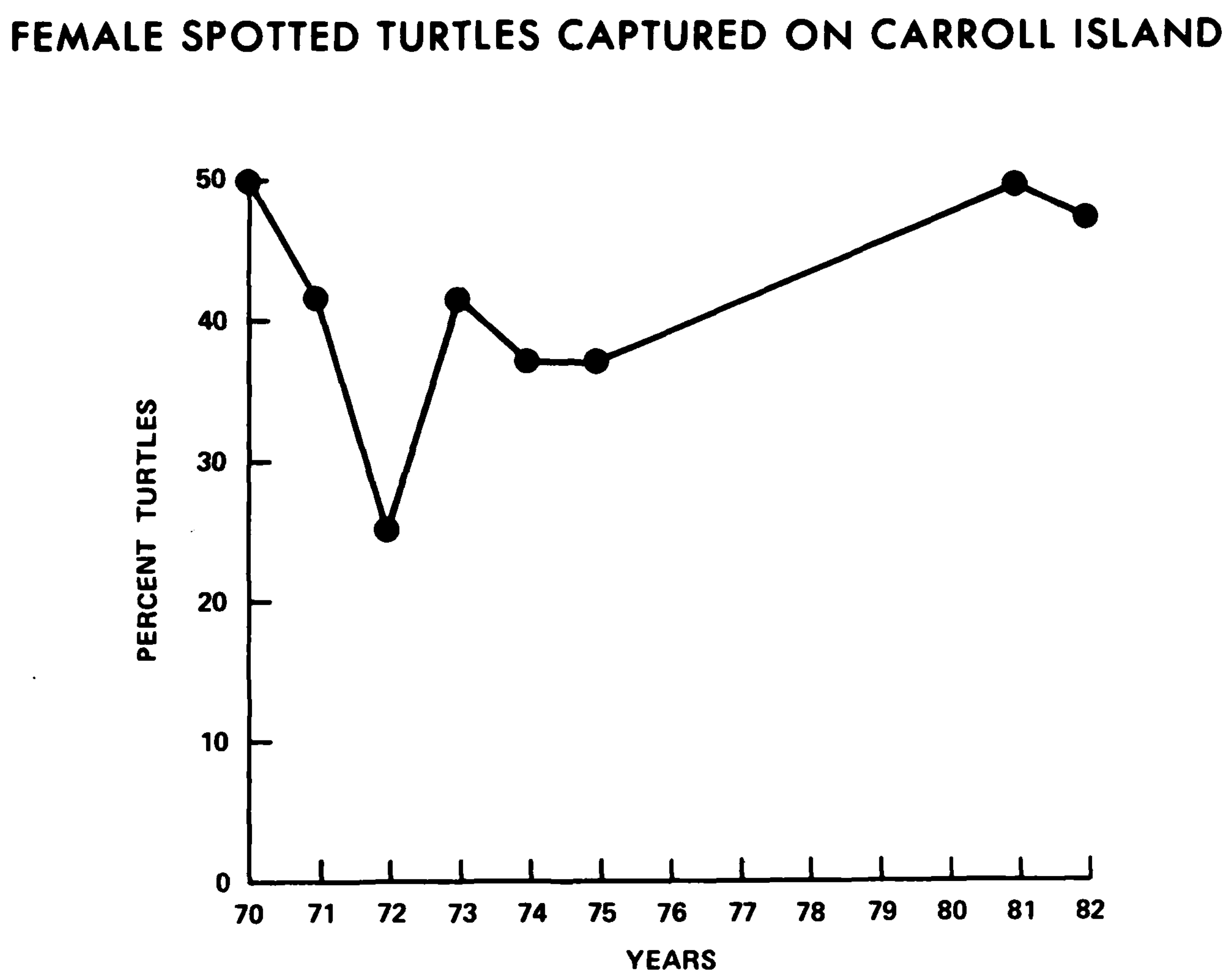

Figure 6. Female Spotted Turtles Captured on Carroll Island

to predation, and exist near the carrying capacity of the environment would be unlikely to show discernable and regular population cycles.

Assuming that the rise in numbers of the turtles was not due to normal population fluctuation, what has caused the decline? Four hypotheses are offered: (1) destruction of habitat, (2) inhibition of reproduction or increased mortality due to chemical contamination, (3) alteration in the sex ratio, and (4) a population crash following the overshooting of the carry capacity of the environment.

Destruction of habitat could have reduced the population of spotted turtles. This hypothesis is partially supported by the observation that a slow reduction and eutrophication of habitat has occured on the HOT side of the island. The number of turtles on the HOT side has declined to an estimated 36 in 1982. In contradiction to this theory is the decline in the COLD side of the island. Turtle populations have gradually declined, yet the habitat appears to have changed little in the last 12 years.

A second hypothesis is that the chemical residues on the island are interfering with the reproduction and longevity of the turtles. Since few data on residual concentrations of the chemicals tested on Carroll Island are available and no tissue samples of the fauna have been examined, this hypothesis is impossible to confirm or refute.

The third hypothesis is derived from the sharp decline in the proportion of female turtles. The number of offspring in a population is directly dependent on the number of females. The sharp reduction in the number of females and therefore reproductive potential could easily account for the population decline. The decline in the proportion of females in the population could be caused by two factors. First, predation or natural catastrophe during egg laying would differentially destroy the female turtles. Second, sex in many reptiles, including turtles, is determined by the temperature during a critical stage of incubation.[7,8,9,10] Either of these factors would cause a decline in the female population. The first hypothesis is difficult to confirm since no records of natural fires or other catastrophes have been kept for Carroll Island. The temperature hypothesis needs additional work on the critical period and temperature for sex determination in *C. guttata*.

The last hypothesis is that the turtle population, when released from an artifical or natural limitation, exceeded the carrying capacity of the environment.

Since spotted turtles have a long period of immaturity, approximately 9 years, a lag period of several years can occur before competition among the adults forces a decline in the population. The reduction in decline from 1975 until 1982 indicates that an equilibrium may have been approached.

A critical element in support of the above hypothesis is the large proportion of juveniles that was seen in the early seventies. In the HOT area almost 34 percent of the turtles collected were juvenile (figure 5). The high reproductive output suggests that the populations were previously limited, either by natural or artifical causes.

In support of the overshoot hypothesis is the recent and stimulating paper of Fowler.[11] He analyzed the population dynamics of large mammals, animals that exist at or very near their carrying capacity (K). These species are often referred to as K-selected. One of the results was the finding that such organisms exhibit their greatest reproductive potential at or near their carrying capacity. These species have not evolved under conditions of rapid environmental change. As the environment fluctuates the organisms may reproduce exponentially and overshoot the carrying capacity of the environment. Time lags induced by population age-structure can cause populations to increase far beyond a theoretical average. As the offspring become mature and compete more intensely for resources, a population crash is likely to occur.

The life-history characteristics of turtles resemble large mammals in several ways. Both have long lifespans, the adults are generally impervious to predation, and they possess comparatively long periods of immaturity. Extrapolation of Fowler's premise to the population of *C. guttata* on Carroll Island is certainly warranted.

The population of *C. guttata* on Carroll Island changed dramatically over the 12-year period of the study. The numbers of turtles were reduced by a half, the juvenile population also decreased, and the proportion of females in the population violently fluctuated. The most likely explanations are that a temperature anomaly or natural catastrophe dramatically reduced the proportion of females. Concurrently, the population overshot the carrying capacity of the environment after cessation of an artifical or natural restriction.

Attributing the population dynamics of the turtle population to the impact of the chemicals deposited on Carroll Island is difficult. Ward[1] compared the proportions of juveniles in the areas downwind of the test sites to the proportions in the COLD sites. Since a higher proportion of juveniles was found in the downwind sites, it was concluded that those areas were under a greater environmental stress. However, even 12 years after the cessation of testing, the proportion of juveniles in the HOT regions is still higher than in the COLD regions (figure 5). A factor other than release from constraints due to chemical tests is very likely contributing to the differences in the proportions of juveniles.

Another explanation for the differences in the two populations is the possibility of there being more than one genetically isolated population on the island. *C. guttata* has been shown to have comparatively small ranges.[12] If migration is not sufficient to maintain a panmictic population, the founder effect could have important impacts. An electrophoretic survey of the blood proteins of *C. guttata* on Carroll Island could provide an indication of the genetic constitution of the population.

Many of the most toxic compounds tested on Carroll Island are known to rapidly hydrolyze into less toxic forms. A study of the actual rates of bioaccumulation and degradation of these materials deposited on Carroll Island coinciding with the current study could have been extremely useful.

The inability of the current data set to discriminate between natural and artifical impacts demonstrates the weaknesses of descriptive work. The lack of comparable mark-recapture data collected before the end of testing greatly hampers the evaluation of the present data set. Soil and tissue samples to determine the amounts of material that the turtles were actually exposed to would have led to an estimate of dose. The present data set, supplemented with chemical and electrophoretic surveys, does serve as an excellent baseline in the event of further testing.

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